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Effect of Salicylic Acid and Beeswax Coating on Quality and Shelf Life of Selected Grape Cultivars

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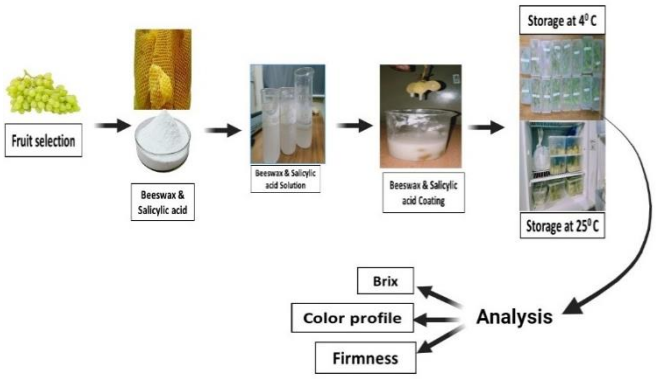
Grape fruit is the most economically important fruit, but due to its highly perishable nature, this fruit faces higher problems in storage and transportation to market across long distances. Edible coatings have shown promise in minimizing post-harvest losses in perishable goods. To address this, the efficacy of beeswax and salicylic acid coatings at various concentrations (0.5%, 1%, 1.5%, and 2%) was evaluated on two grape cultivars (Toffee and Gola) stored at 4°C and 25°C. A completely randomized design was employed for the experiment. Application of salicylic acid and beeswax significantly decreased physiological weight loss (PWL), pH, and total soluble solids (°Brix) maintained firmness, and extended the shelf life of fruits compared with control samples. While total soluble solids, firmness, pH, weight loss, and sensory properties generally deteriorated in control samples during storage, the application of salicylic acid and beeswax significantly mitigated these changes. The 1.5% beeswax concentration exhibited a notable impact and postponed the deterioration of quality parameters.
Keywords: Grapes, beeswax, salicylic acid, edible coating, storage, shelf life, sensory.

INTRODUCTION

The family *Vitaceae* includes the grape (*Vitis vinifera*) which is indigenous to temperate climate of the north hemisphere and includes types that can be used to make juice or wine, dried to make raisins, or eaten as table grapes (Atak, 2025). Numerous active components are present in grape such as flavonoids, procyanidins, polyphenols, proanthocyanins and stilbene derivative resveratrol (Lopes *et al*., 2025). In nutritional point of view, grapes in the diet particularly the red ones, are abundant in phenolic compounds. These compounds are recognized as promoters of human health, often in association with other bioactive compounds like carotenoids, vitamin E, and vitamin C. It is also a healthy source of vitamins like B1 and B2 and minerals such as calcium (Ivanov *et al*., 2025).

Grapes are the economic fruit, approximately with yearly output of 69 million tons (Monteiro *et al*., 2025). In Pakistan, grapes are grown over an area of 15,302 ha, with an average yearly production of 64,317 tonnes (Khan *et al*., 2020). The majority of Pakistan's grapes are grown in Baluchistan.



However, warmer regions like Multan, Bahawalpur, and Rahim Yar Khan have started to grow grapes on a very large scale (Anjum *et al*., 2022). The most popular grape types in Pakistan include Thompson, Narc Black, Crimson, Sultana, and King Ruby. More varieties of Vitis vinifera are

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categorized as Cotton Candy, Moon Drops, Flame Seedless, and Red Globe (Sharma *et al*., 2020). The property that the table grapes possess increases their value, which raises their demand in the market, and daily consumption increases (del Castillo, 2025).

The chemical composition, mineral content, and functional properties of Benita ca grape (*Vitis vinifera L.*) indicate that insoluble fiber content is higher (79%; 36.4 g/l00 g) for compounds with functional characteristics (Castro *et al*., 2025). Vitamin C (26.25 mg ascorbic acid/l00 g) and anthocyanin (l3l mg/l00 g) are also present. Minerals rich in iron, potassium, zinc, manganese, and calcium can be used as an ingredient in food and/or as a nutritional supplement for health (Vieira *et al*., 2025). However, applying an edible coating of beeswax and salicylic acid is known to extend their shelf life (Iqbal *et al*., 2024). In that study, two grape varieties—Toffee and Gola—named in the regional tongue, were employed. Grapes were sorted by color, size, and degree of fruit damage. For the coating of grapes, different concentrations of beeswax and salicylic acid were created. The 'Toffee' cultivar was treated as whole bunches, while 'Gola' grapes were separated into individual berries before coating. It was immersed in the coating solution for 5 minutes, left for 2 minutes, and then placed in storage boxes. The temperatures of 4°C and 25°C were chosen as the storage conditions (Ehteshami *et al*., 2024).

The goal of this study was to maintain the nutritional value of grapes while extending their shelf life. While edible coatings have been explored, the specific combination of beeswax and salicylic acid on these particular grape cultivars under varying storage conditions, especially in the context of the local Pakistani market, remains underexplored. This study hypothesized that beeswax and salicylic acid coatings would effectively reduce post-harvest deterioration and prolong the shelf life of 'Toffee' and 'Gola' grape cultivars.

MATERIALS AND METHODS

***Collection of samples*:** The specific varieties of Grapes (*Vitis vinifera L.*) "Gola" and "Toffee" were chosen and collected in June from fields situated in Multan, Punjab, Pakistan. At the time of collection, both grape varieties were fully ripe and light green in color with uniformity in size.

***Sample preparation*:** After the collection of samples, any berries that were harmed, questionable, or unhealthy were removed. The cleaning of the grape surface removed all impurities that could have prevented the coating from adhering properly.

***Preparation of coating*:** The emulsion of beeswax was formulated according to the methods suggested by (Vergel-Alfonso *et al*., 2025), and Beeswax (76.8g) was set up in a 1L tank and was heated to a temperature of between 80 and 90 °C over the course of several minutes, starting at 70°C. The wax (100% natural was purchased from Chiltan Pure from Lahore, Pakistan) was then continuously stirred while 12.8 mL of linolenic acid was added ($C_{18}H_{30}O_2$, was purchased from Pharma Compass, Lahore, Pakistan). Then, 25.6mL of glycerol ($C_3H_8O_3$), an emulsifying agent, was added. Following this, 524.8 mL of preheated distilled water, which had been stirred continuously for five minutes, had its temperature gradually increased to 80-90°C, and the mixture was then dried by air. The prepared emulsion was chilled and kept at room temperature in a covered beaker prior to use. The emulsion solidified after a couple of hours. Salicylic acid ($C_6H_4(OH)CO_2H$, purchased from GM Scientific store, Multan, Pakistan) was added to 100mL of solution at various concentrations while being magnetically stirred (Model Number: EIE-223ML) and shaken (Model Number: CLS-01O) at a temperature of 25°C.

***Implementation of coating*:** In order to check the quality and shelf life of both grape varieties, the fruits were coated for five minutes before being drained (Fig. 1). Then, they were held at 4°C for 14 days and at 25°C ambient temperatures for 14 days (Oliveira *et al*., 2025), (Table 1).

Supplementary materials

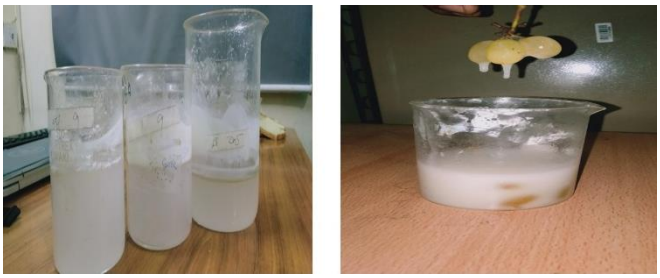

Figure 1. Application of Beeswax and Salicylic Coating on Grapes.

***Total Soluble Solids (TSS)*:** Total soluble content of the fruits was measured with the help of an ABBE Refractometer (Model Number: HV-1317). The results were taken in °Brix (Milošević *et al*., 2025).

***Potential of hydrogen*:** The pH of fruit juice was measured according to the methods of AOAC. (2023) using a standard calibrated pH meter (Cao, 2023; Sivaprakasam *et al*., 2025).

***Drop in weight (%)*:** The weight loss (%) of the coated grapes kept at different temperature was measured after every 2 days interval. Weight loss (%) was calculated by the following (Hassan & Ali, 2025).

Weight loss (%)
= initial weight – final weight / initial weight x 100

***Resoluteness*:** The grape's purposefulness was manually assessed. It was decided to use a scale from 1 to 5, with 1 denoting Extremely firm is the strongest, followed by firm, moderately firm, mild, and very soft on the base of resoluteness.

***Color*:** The spectrophotometer (YS-3010) was used to gauge the color of the grapes. Three points were used to take

readings. The coordinates a* and b* of CIE L* were noted. These coordinates were defined as: L* (Lightness), a* (- greenness to + redness), and b* (- blueness to + yellowness) (Ruiz-Serrano *et al*., 2025).

***Sensory*:** Sensory evaluation of the grape was done according to the method described in (Hejazi *et al*., 2025). For the examination of sensory characteristics, a 9-point hedonic scale was used. The sensory qualities of the grape and the control sample were assessed, including colour, taste, flavour, aroma, texture, appearance, and total acceptability.

***Statistical analysis*:** The analysis of variance (ANOVA) was carried out using a completely randomized design (CRD), and to identify the significant differences between the mean values, Tukey's test was applied. The study's hypothesis was assessed at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

***Brix of grapes*:** They are measured with the help of a refractometer and are expressed in Brix. The results regarding the Brix of grapes stored at 4°C indicated that the value was in the range of 16.3-17.9. The application of beeswax increases the total soluble solids in a dependent manner e.g., application of beeswax @ 1.50% showed the highest total soluble solids. The results during storage varied significantly. However, edible coatings did not show any impact (Table 2). The maximum solids were recorded on the first day of storage, and the least total soluble solids (TSS) were recorded on the 14th day of the research study. In Comparison to 4°C, total soluble solid contents varied significantly as a function of treatments, storage interval, and varieties. Overall, the TSS varied from 14.9-17.9%.

Like the first trial, beeswax coating enhances the TSS in a dose-dependent manner. It was evident that application of edible coatings retarded the loss in soluble solids, i.e., the TSS decreased from 17.2 to 14.9 during 14 days in the control treatment, while 15.8 to 15.7 % TSS were recorded (1.50% BW and 0.5% SA) and (1.50% BW and 1 % SA). Both varieties of grapes showed almost the same behavior in all treatments (Table 3).

The results regarding TSS are in close agreement with the findings of HYPERLINK \l "Shahzad", and in this research, aloe Vera gel was used as a coating to maintain the quality of grapes. The storage conditions affect the quality of grapes, and refrigeration temperature usually reduces the rate of deterioration, thus increasing the shelf life of the product (Moradinezhad *et al*., 2025). However, storage at 4°C for long-term time can initiate the process of chilling injury after 21 days of storage (As evident from our results). It was highlighted in the present research that edible coatings containing beeswax @ 1.5% and 1.25 % have high soluble solids during storage.

Table 1. 1. Treatment plan of salicylic acid and beeswax coating on grape cultivars.

Treatment	Salicylic acid	Beeswax	Salicylic acid	Beeswax
T_0	Control	Control	Control	Control
T_1	0.5%	4.50g	0.5%	5.625g
T_2	1.0%	4.50g	1.0%	5.625g
T_3	1.5%	6.75g	1.5%	9.000g
T_4	2.0%	6.75g	2.0%	9.000g

Table 2. Mean values for brix of grapes stored at 25°C.

Brix	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	17.20	17.10	16.00	15.90	15.10	14.90	16.03^{b}
T_1	17.20	17.20	16.40	16.30	15.40	15.30	16.30^{abcd}
T_2	17.30	17.30	16.50	16.50	15.50	15.50	16.43^{abc}
T_3	17.80	17.80	16.60	16.60	15.70	15.30	16.63^{ab}
T_4	17.80	17.70	16.70	16.60	15.60	15.50	16.65^{a}

***Color profile*:** They are measured with the help of a colorimeter. The results regarding lightness of grapes stored at 4°C indicated that the value was in the range of 5.16-39.90. The application of beeswax increases the lightness (L value) in a dose-dependent manner, e.g., application of beeswax @ 1.50% showed the highest L value. The results during storage varied significantly. However, edible coatings did not show any impact. The maximum lightness was recorded on the first day of storage, and the least lightness was recorded on the 14th day of the research study.

In comparison to 4°C, lightness varied significantly as a function of treatments, storage interval, and varieties. Overall, the lightness varied from 4.24 to 39.90%. Similar to the first trial, beeswax coating enhances the lightness in a dose-dependent manner (Vergel-Alfonso *et al*., 2025). It was evident from Table 4 that application of edible coatings retarded the loss in lightness, that is, the lightness decreases from 39.90 to 14.91 during 14 days in the control treatment, while 11.85 to 31.09 % L value was recorded (1.50% BW and 0.5% SA) and (1.50% BW and 1 % SA). Both varieties of grapes showed almost the same behavior in all treatments (Table 4, 5).

Table 3. Effect of edible coatings on Brix of grapes stored at 4°C.

Brix	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	17.20	17.10	16.90	16.80	16.50	16.30	16.80^{b}
T_1	17.20	17.20	17.10	17.00	16.70	16.60	16.97^{abcd}
T_2	17.30	17.30	17.20	17.20	16.80	16.70	17.08^{abc}
T_3	17.70	17.70	17.30	17.30	16.90	16.90	17.30^{ab}
T_4	17.80	17.70	17.40	17.30	16.90	16.80	17.31^{a}

Table. 4 Mean values for L* at 25°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	16.49	22.07	16.83	14.75	12.17	26.82	18.19^{ab}
T_1	20.41	17.45	6.36	16.75	17.02	15.86	15.64^{abc}
T_2	14.01	17.56	23.85	11.16	14.32	8.30	14.87^{abc}
T_3	08.55	14.10	13.83	13.30	4.25	9.39	10.57^{c}
T_4	13.33	20.72	15.40	7.13	14.85	9.13	13.42^{abc}

The results regarding a* value of grapes stored at 4°C indicated that the value was in the range of -2.26-4.02. The application of beeswax changes the a* value in a dose-dependent manner, e.g., application of beeswax @ 1.50% showed the highest a* value. The results during storage varied significantly. However, edible coatings did not show any impact. The maximum a* value was recorded on the first day of storage, and the minimum value of a* was recorded on the 14th day of the research study. In Comparison to 4°C, the value of a* (-greenness to + redness) varied significantly as a function of treatments, storage interval, and varieties. Overall, the a* value varied from -2.26 to 13.91%.

Similar to the first trial, beeswax coating enhances the value of a* in a dose-dependent manner. It was evident from Table 5 that application of edible coatings retarded the loss in color, that is, the value of a* decreases from 2.11 to 2.40 during 14 days in the control treatment, while 4.72 to 2.67 % a* value was recorded (1.50% BW and 0.5% SA) (1.50% BW and 1 % SA). Both varieties of grapes showed almost the same behavior in all treatments (Table 6, 7).

Table 5. Mean values for L* of grapes stored at 4°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	39.89	36.49	22.13	20.41	10.05	14.90	23.97^{abc}
T_1	33.72	21.58	23.25	20.70	30.46	17.56	24.55^{a}
T_2	30.02	21.15	30.35	22.26	23.92	16.97	24.11^{ab}
T_3	19.69	20.42	10.07	23.21	14.84	36.55	20.80^{b}
T_4	24.95	27.70	8.97	14.71	24.02	22.48	20.47^{bc}

Table 6. Mean squares for a* at 25°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	16.49	22.07	16.83	14.75	12.17	26.82	18.19^{ab}
T_1	20.41	17.45	6.36	16.75	17.02	15.86	15.63^{abc}
T_2	14.01	17.56	23.85	11.16	14.32	8.30	14.83^{abc}
T_3	8.55	14.10	13.83	13.30	4.25	9.39	10.56^{c}
T_4	13.33	20.72	15.40	7.13	14.85	9.13	13.42^{abc}

The results regarding a* (-greenness to + redness) of grapes are in close agreement with the findings of HYPERLINK \l "Hassan", and in this research, cellulose coating delays quality deterioration in harvested table grapes during cold and ambient storage conditions. However, storage at 4°C for long-term time can initiate the process of chilling injury after 21 days of storage (As evident from our results) (Nisari *et al*., 2025). It was highlighted in the present research that edible coatings containing beeswax @ 1.5% and 1.25 % can retain a high a* value during storage.

The results regarding the b* value of grapes stored at 4°C indicated that the value was in the range of 3.02-17.42. The application of beeswax changes the b* value in a dose-dependent manner, e.g., application of beeswax @ 1.50% showed the highest b* value. The results during storage varied significantly. However, edible coatings did not show any impact. The maximum b* value was recorded on the first day of storage, and the least value of b* was recorded on the 14th day of the research study.

In Comparison to 4°C, the value of b* (-blueness to + yellowness) varied significantly as a function of treatments, storage interval, and varieties. Overall, the b* value varied from 2.17 to 32.40%.

Like the first trial, beeswax coating enhances the value of b* in a dose-dependent manner. It was evident from Table 8 that application of edible coatings retarded the loss in color, that is, the value of b* changes from 7.17 to 8.49 during 14 days in the control treatment, while 8.26 to 9.18 % b* value was recorded (1.50% BW and 0.5% SA) and T15 (1.50% BW and 1 % SA). Both varieties of grapes showed almost the same behavior in all treatments (Table 8, 9).

Table 7. Effect of edible coatings on a* value of grapes stored at 4°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	-1.33	1.39	1.14	4.01	1.01	3.16	1.56^{a}
T_1	-2.25	-0.14	-0.93	0.98	-0.43	2.61	-0.03^{b}
T_2	-1.40	1.76	0.68	-1.27	-1.42	0.61	-0.17^{b}
T_3	-1.74	-1.74	1.61	-1.17	1.47	-1.48	-0.51^{b}
T_4	-1.98	1.13	-0.57	2.45	-0.28	-0.32	0.07^{b}

Table 8. Mean values for b* at 25°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	8.15	11.29	11.01	9.47	6.75	8.13	9.12^{c}
T_1	9.52	10.08	12.14	13.96	9.68	10.13	10.92^{abc}
T_2	11.10	13.06	11.92	12.85	9.24	14.77	12.16^{ab}
T_3	9.27	11.65	8.82	13.05	10.85	12.03	10.95^{abc}
T_4	11.14	9.07	8.86	10.17	5.91	10.35	9.24^{c}

The results regarding b* (-blueness to + yellowness) of grapes are in close agreement with the findings of (Basdeki *et al*., 2025) and in this research, incorporation of anthocyanins extracted from winery grape pomace into polyvinyl alcohol/starch films was used to examine the freshness of grapes from winery pomace. The Storage conditions affect the quality of grapes, and refrigeration temperature usually reduces the rate of deterioration, thus increasing the shelf life

of the product. However, storage at 4°C for long-term time can initiate the process of chilling injury after 21 days of storage (As evident from our results). It was highlighted in the present research that edible coatings containing beeswax @ 1.5% and 1.25 % can retain a high b* value during storage.

Table 9. Effect of edible coatings on b* value of grapes stored at 25°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	7.16	11.17	8.25	3.33	8.62	8.48	7.85[a]
T_1	11.48	8.12	4.02	7.79	7.17	10.36	8.15[a]
T_2	7.55	8.59	7.13	9.60	7.28	3.70	7.30[a]
T_3	6.15	32.42	7.05	9.22	2.16	6.54	10.60[a]
T_4	8.32	4.83	9.65	4.21	7.35	6.63	6.82[a]

***Chroma*:** The results regarding grapes stored at 4°C indicated that the value was in the range of 3.13-17.45. The application of beeswax changes the Chroma in a dose-dependent manner, e.g., application of beeswax @ 1.50% showed the highest Chroma. The results during storage varied significantly. However, edible coatings did not show any impact. The maximum Chroma was recorded on the first day of storage, and the minimum Chroma value was recorded on the 14th day of the research study. In Comparison to 4°C, the value Chroma varied significantly as a function of treatments, storage interval, and varieties. Overall, the Chroma value varied from 3.13 to 32.40%. Similar to the first trial, beeswax coating enhances the Chroma in a dose-dependent manner in agreement with a previous study by (Andrea *et al*., 2025). It was evident that application of edible coatings retarded the loss in Chroma, i.e., the value of Chroma changed from 7.80 to 9.37 during 14 days in the control treatment, while 9.56 to 9.57 % Chroma were recorded in T4 (1.50% BW and 0.5% SA) and in 1.50 % BW and 1 % SA. Both varieties of grapes showed almost the same behavior in all treatments (Tables 10, 11).

***Firmness*:** The maximum force required to compress a food between the teeth is called firmness. The results regarding firmness indicate that grapes stored at 4°C showed see-saw trends. Firmness increases from 2.33 to 3.0 % of control during the initial 14 days of storage and later drops to 2.81 on 21 days and 1.89 at 28 days. The application of beeswax coating improves the firmness in a dose-dependent manner. The edible coating containing a higher value of beeswax showed better retention of texture even after 28 days (2.97 for Toffee variety and 2.72 for Gola variety).

The contrasting results were recorded when grapes were stored at 25°C. The firmness increased during the first 7 days of storage and then decreased drastically from 7 to 14 days. The lowest score for firmness was recorded in the controlled treatment, that is, 1.77 and 1.75 in V1 and V2 (Toffee and Gola Varieties), respectively. The edible coating containing different formulations of beeswax and salicylic acid retarded the rate of textural changes e.g., the treatment T4 (1.50% BW and 0.5% SA) and in 1.50 % BW and 1 % SA, that showed the better firmness score of 2.19 and 2.20 at day 14 respectively as previously demonstrated by (Kamboj *et al*., 2025), which increased postharvest quality of mango by applying cinnamic acid enriched xanthan gum coatings.

Table 10. Mean squares for Chroma at 4°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	8.26	11.40	11.03	10.31	6.83	8.75	9.45[c]
T_1	9.82	10.11	12.20	14.03	9.72	10.45	11.07[abc]
T_2	11.20	13.54	12.01	12.91	9.34	14.78	12.30[ab]
T_3	9.43	11.80	9.14	13.13	11.13	12.12	11.11[abc]
T_4	11.30	9.22	8.92	10.42	5.97	10.35	9.36[c]

Table 11. Effect of edible coatings on Chroma value of grapes stored at 25°C.

L*	0 Days		7 Days		14 Days		Means
	Toffee	Gola	Toffee	Gola	Toffee	Gola	
T_0	7.82	11.20	8.31	14.91	9.36	8.85	10.08[a]
T_1	11.61	8.76	7.41	8.74	7.35	10.33	9.02[a]
T_2	7.73	8.69	7.58	9.76	8.50	5.15	7.92[a]
T_3	6.31	32.39	7.15	9.99	2.63	8.47	11.15[a]
T_4	8.82	6.79	10.09	5.05	7.81	8.55	7.85[a]

***Weight loss*:** The results regarding the weight loss of grapes stored at 4°C indicated that at first, weight loss was high and after 14th days started decreasing. The application of beeswax changes weight loss in a dose-dependent manner, e.g., application of beeswax @ 1.50% showed the highest weight loss value. The results during storage varied significantly. However, edible coatings did not show any impact. The maximum weight loss values were recorded on the first day of storage, and the least weight loss value was recorded on 14 days of the research study, consistent with (Güzin *et al*., 2025). In Comparison to 4°C, the weight loss value varied significantly as a function of treatments, storage interval, and varieties. Similar to the first trial, beeswax coating enhances the weight loss value in a dose-dependent manner. It was evident from the graph 4.6.2 that the application of edible coatings retarded the loss in weight value. Both varieties of grapes showed almost the same behavior in all treatments. Salicylic acid also affects the sensory attributes of the grapes.

***Conclusion*:** The current experiment showed a significant effect of coating on the storage and shelf life of grapes. The storage environment affects the food quality, which is often more challenging in food transportation, leading to food insecurity. The importance of salicylic acid and beeswax coating on grapes addresses the concern of storing or transporting food without its spoilage and supports the food chain to make the food system sustainable. This research can contribute to a future perspective as the trend is shifting

toward online food delivery systems, so the maximum food loss can be prevented.

CRediT author statement: A. Amjad designed, completed the experiment; S. Akram, R. Mehboob, S. Zafar prepared the original draft; K. Afzal, M. Israr, W. A. Khan, N. Javaid reviewed and finalized the draft.

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***SDGs addressed*:** Zero Hunger; Good Health and Well-being; Responsible Consumption and Production.

***Policy referred*:** Handling perishable food and reducing losses to sustain the food chain **(**FAO Post-harvest Management Guidelines.

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